Chapter 5

Design Techniques for Flood Damage Reduction

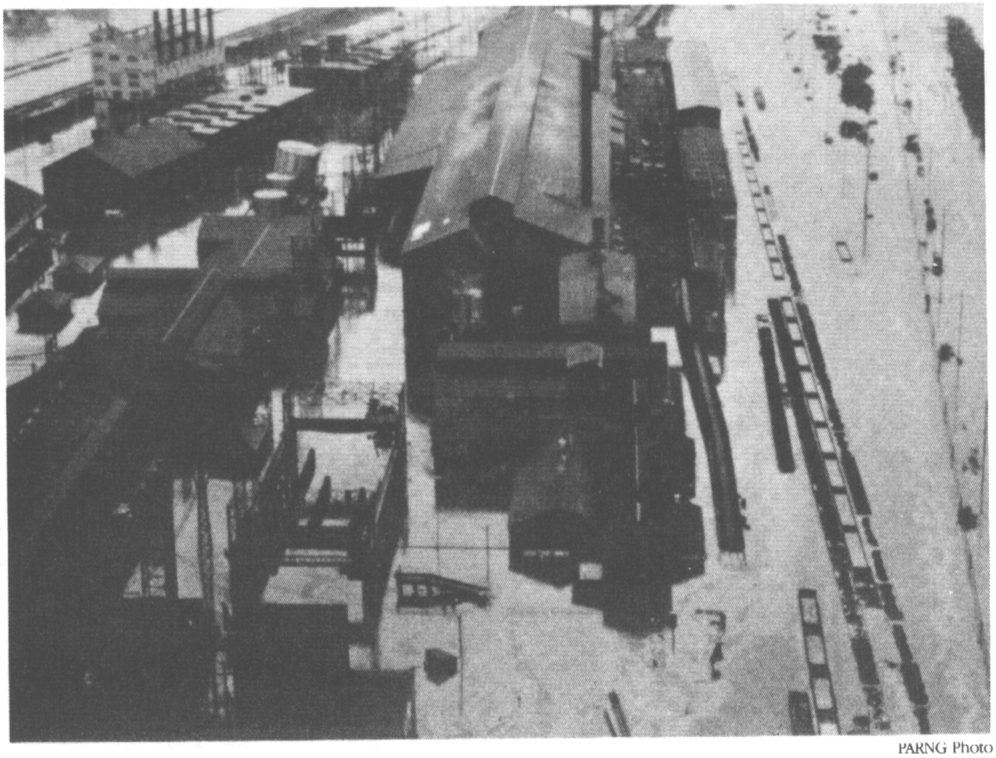
The pre-design analysis outlined in the previous chapter enables the designer to incorporate data on flood-related restrictions and opportunities into the client's basic program of the needs and requirements that the design must meet. At this point the focus shifts to generating design alternatives and, ultimately, to detailed design decisions.

Type of Project

The type of design project has a direct bearing on flood damage mitigation strategies. The variations most relevant to flooding include multiple versus single buildings, new versus existing buildings, and building use.

Multiple Buildings. The complexity of siting decisions is affected by whether a project involves a single building or multiple buildings. With a single building it is a matter of siting the building on that part of the site least likely to suffer flooding. With multiple buildings, site use can vary from clustering all buildings on one part of the site to dispersing the buildings throughout the site but locating each of them above base flood elevations.

New or Existing Buildings. New construction offers wide latitude in making site decisions and in deciding on the use of flood-related design techniques. Conversely, projects involving expansion, improvement, preservation or rehabilitation of existing buildings require special consideration of design alternatives. Site choice is predeter-



PARNG Photo

Flooding can affect all types of development. It can damage either new or existing buildings, and is a relevant design factor for industrial, commercial, and residential uses. In some projects flooding must be considered in relation to multiple buildings, while others may involve only a single building.

Gordon H. Schenck, Jr.

Case Summary: Corte Madera Creek Marin County, California

A Flood Control Study

Sponsored by:
U.S. Army Corps of Engineers
San Francisco District

Prepared by:
Royston Hanamoto,
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With the assistance of:
Pflueger Architects
Water Resources Engineers
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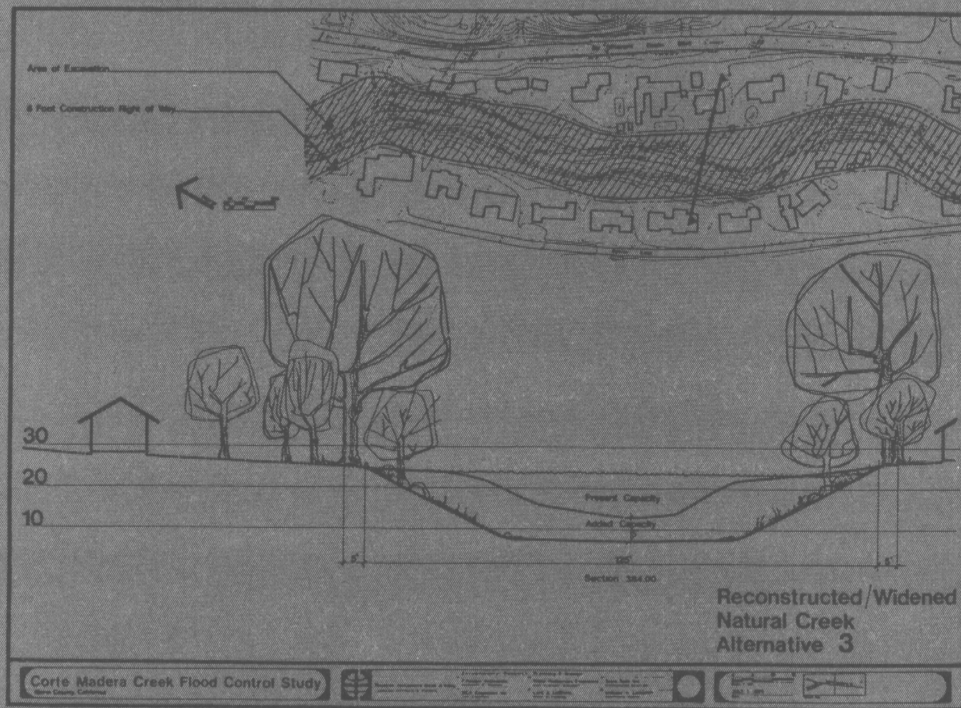


The final proposal recommends widening and deepening the creek bed to meet the requirements of the 100-year flood. After excavation the creek bed is to be restored to its natural condition with trees, shrubs, and ground cover.

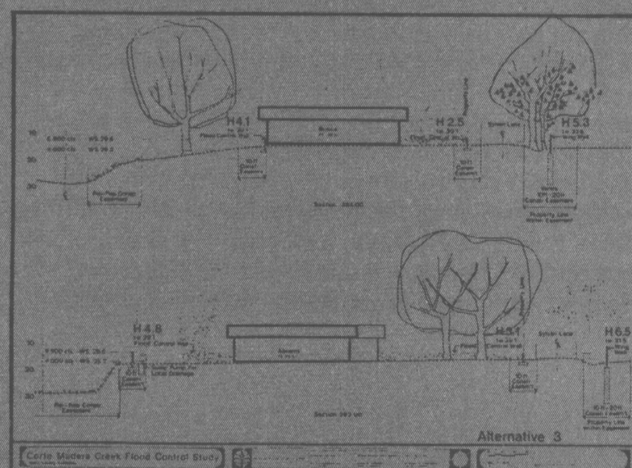
Corte Madera Creek, located in Marin County, California, is one of several major channels that drain 28 square miles of the eastern slopes of Mt. Tamalpais. The 70-acre area studied in the project coincides with the floodplain of Corte Madera Creek. The 100-year floodplain, which varies in width from 100 to 4000 feet, is populated by housing, schools, roads, and commercial facilities.

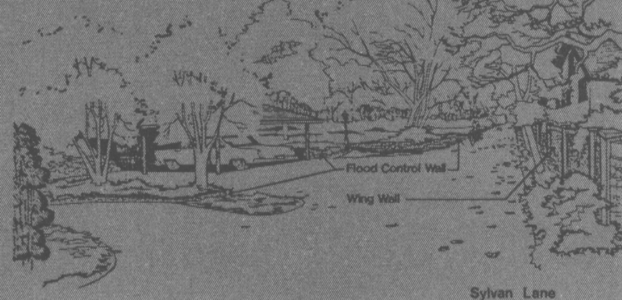
The study was undertaken to investigate alternative methods of providing flood control for an area in which existing buildings were located on hazardous, flood-prone sites. The principal goal was to make the immediate area safe from flooding without destroying the natural quality and character of the creek. In achieving this end, strategies adopted were to avoid increasing the flood hazard for downstream residents and to preserve the area's ecological system.

During the course of the study a number of alternatives encompassing a variety of flood damage reduction techniques were analyzed. Included among the alternative strategies were proposals to:

- Reconstruct the creek using concrete channel linings to contain the flow of flood water.
- Enlarge the creek and clear it of vegetation and debris to improve water flow.
- Build flood walls and berms along the banks of the creek.
- Provide overflow culverts under either the existing creek bed or an adjoining street.
- Remove some of the existing houses to create a waterfront park that would accommodate flood waters.

After evaluating the advantages and disadvantages of the various proposals, the study recommended an approach that combined several techniques. It was agreed that the stream channel should be widened and deepened to improve the flow of water, but that, trees, shrubs, and ground cover should be retained or restored instead of using concrete linings. To further protect creekside residents from the 100-year flood, it was proposed that several houses be elevated above the base flood elevation and that protective walls be constructed along some sections of the creek. This solution provided the necessary degree of protection yet maintained the natural character of the stream, which was valued highly by the community.





Channel improvements are to be combined with floodwalls at strategic points to protect existing properties.

mined unless relocation is feasible. Older buildings often have structural limitations and seldom prove to be feasible candidates for elevation above the base flood level. Additional constraints arise if the project involves a historical building that cannot be altered to the extent of reducing its historical integrity. All such issues affecting existing buildings must be analyzed in relation to strategies for flood damage reduction.

Type of Use. Residential, commercial, industrial, and public building projects have different factors influencing the choice of techniques for flood damage reduction. First, in meeting National Flood Insurance Program (NFIP) regulations, residential structures are required to be above the base flood elevations, while other uses have the option of being either elevated or floodproofed to the same level. Second, the type of use also influences site decisions. For example, the use of clustering techniques will be different for residential buildings than for commercial or industrial uses. Third, the type of use can affect the site layout in terms of required access to buildings during flooding, and will influence the methods for controlling water runoff.

Finally, different uses influence floodproofing techniques. Waterproofing is generally more relevant for commercial buildings that have easily damaged materials and finishes, valuable records, and vulnerable contents. Wet floodproofing might be more appropriate for an industrial building that is easier to clean and has more easily protected contents.

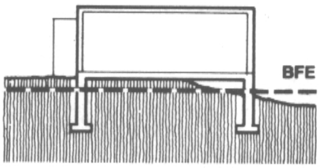
Applicability of Design Techniques

As previous chapters have made clear, buildings ideally will be located so that they are not subject to flooding. Yet there are still a variety of situations where this ideal is impractical or unnecessary and that call for special measures to reduce flood damage. For example, when:

- The project site is not itself in a flood hazard area, but is where development might increase flood levels elsewhere.
- Buildings are located in a fringe area that is subject to only mild flooding.
- Buildings can be cost-effectively floodproofed to achieve an acceptable level of safety.
- The project includes existing buildings that, due to historical or economic significance or an existing urban infrastructure, must remain in a flood-prone area.
- Existing buildings are to be removed from a flood hazard area, but the period of amortization will require temporary protection.

U.S. Army Corps of Engineers

Buildings must be located on the part of the site that analysis of basic flood data has indicated is above the Base Flood Elevation (BFE).



Site Design Techniques

Site design techniques for flood damage reduction fall into two categories—distribution and density of built elements on the site and control of storm water runoff. These categories represent different types of problems to be addressed in site design in relation to mitigating flood damage both on the site and throughout the region. The range of available techniques should be used in varying combinations to fit the unique circumstances of each site and the associated design program.

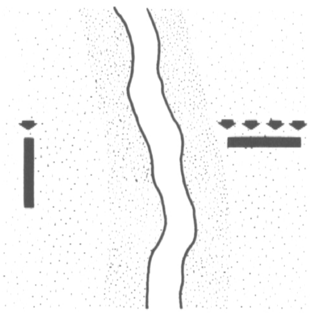
Distribution and density is, foremost, a question of how to locate and orient buildings on the site. Related concerns are the determination of circulation and access routes and the alteration of site topography through excavation and use of fill material.

Siting Individual Buildings. The primary objective in siting individual buildings is to locate structures so that they will be safe (or can be made safe) from flooding. In practice this means locating on that part of the site that analysis of basic flood data has indicated is above the base flood elevation. However there are other factors to be considered.

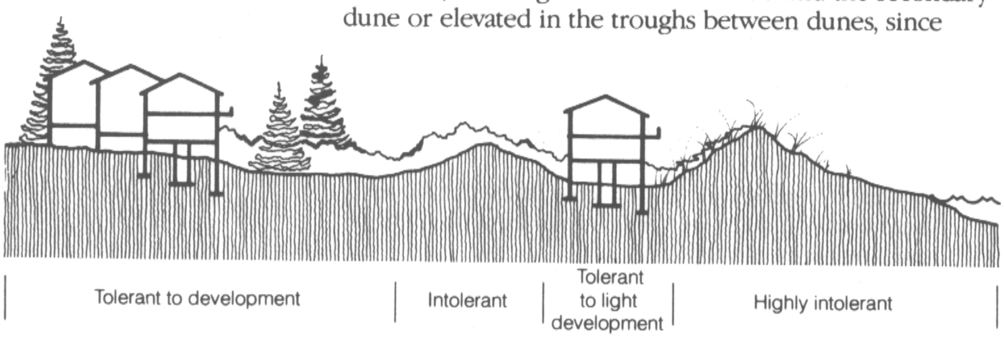
Nonresidential structures can use a combination of elevation and waterproofing to achieve the required degree of safety, as long as they are not located in the floodway or coastal high hazard area. For all structures, the designer should consider the potential for going beyond regulatory minimums, thus providing greater protection wherever possible. Some sites, for instance, allow buildings to be located completely outside the flood fringe, and this should be done wherever possible.

Buildings should also be oriented so that foundations and floodproofed walls minimize obstruction of flood flows. Natural drainage lines and other natural features that help control storm water runoff should be preserved. These measures avoid raising the level of flood waters and minimize negative impacts on downstream property.

Coastal areas require additional safeguards in locating buildings. There must be no construction on beaches or dunes; buildings should be sited behind the secondary dune or elevated in the troughs between dunes, since



Where some construction is allowed in the flood fringe, buildings should be oriented to minimize obstruction of flood flows.



Buildings in coastal areas must be sited in areas that are tolerant to development in order to minimize damage to both the buildings and the natural balance of the coastal ecosystem.

Cluster development to reduce flood damage

Cluster development is frequently used in situations that are not ideally served by traditional zoning and subdivision layouts. It provides flexible alternatives for developing parcels of land that are affected by such special circumstances as flooding. Clustering techniques require specific local zoning laws, which are usually enacted as Planned Unit Development (PUD) ordinances.

Using cluster techniques, part of a site can be developed at higher densities than would be permitted under traditional zoning, leaving the remainder of the site as open space. In a flood-prone area, buildings can be clustered on the part of the site that is safe from flooding, leaving the flood-prone area free of buildings. The remaining open space is then available for low-intensity uses, such as recreation, conservation, or parking, depending on the nature of the project.

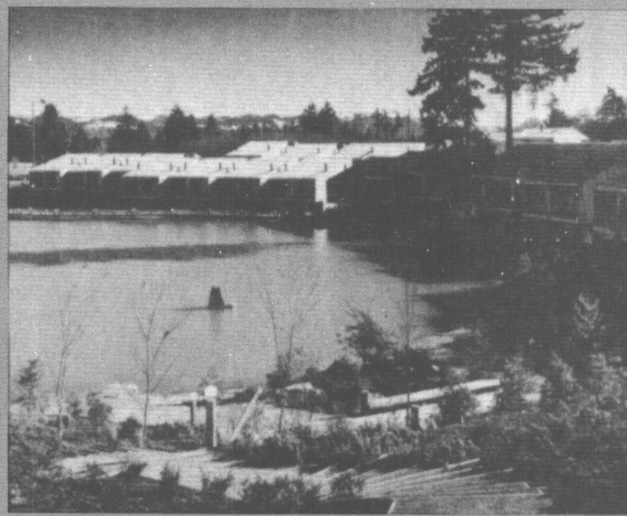
Foremost of the flood-related benefits of cluster development is that buildings are not located on the flood-prone portions of the site. Clustering also minimizes streets, thus reducing the use of impervious surfaces that increase the rate of water runoff. In addition, open space protects existing drainage courses and permits continued infiltration of water in areas left undeveloped.

Cluster techniques offer advantages beyond reduced flood damage. The need for less extensive street and utility systems results in lower construction and maintenance costs. Shorter roadways also reduce the energy required both for construction and for driving the distance of the streets after they are in use. Such savings can have a major significance in large projects.

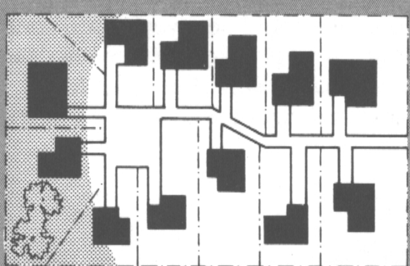
The drawings at left illustrate how flood damage reduction can be achieved using cluster development in a residential setting. The first drawing shows a hypothetical site subdivided, using traditional zoning, into single detached dwellings on large individual lots. As can be seen, four of the lots would be affected by potential flooding and there would be considerable damage to the natural terrain and a high proportion of impervious surfaces.

The second illustration shows the same detached dwellings, but on smaller lots. Consequently, all dwellings are located outside the flood-prone area and there is more open space and a lower proportion of impervious surface on the site. The result is protected building sites and better control of water runoff.

The third drawing takes the cluster technique a step farther by using attached, townhouse-style dwellings. This provides even more open space and minimum street coverage.

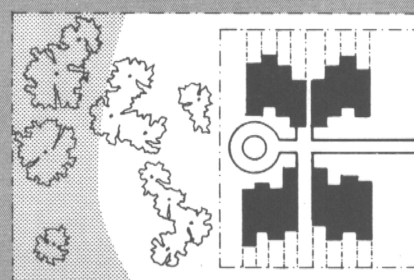


James K. M. Cheng, AIA Journal



Conventional site plan using large lots and single detached dwellings.

Another example of single detached dwellings, but clustered on smaller lots.

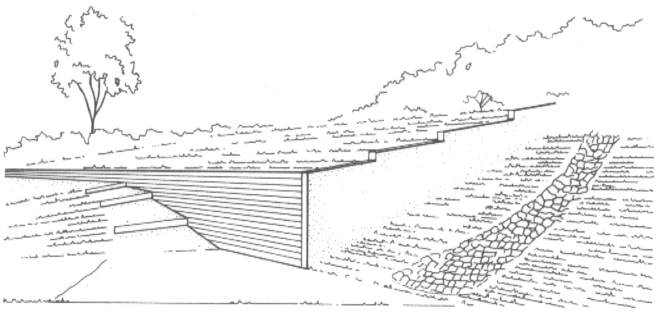


Clustered site plan using attached dwellings and small lots, with a large portion of the site left as open space.

these areas are generally more tolerant to alteration. It is also important that the stabilizing composition and vegetation of dune systems not be disrupted. Access to beaches should be carefully controlled, using elevated walkways to avoid damaging the dunes. And, buildings should not be located, nor should any fill material be used, in wetland areas.

Siting Multiple Buildings. Where multiple buildings are to be placed on the site, the objective when locating structures is the same as with an individual building. The approach to achieving this objective, however, can vary with project circumstances. One approach is to disperse buildings throughout the site, applying the criteria discussed above to each building.

An alternative to dispersal, where local zoning ordinances allow, is grouping buildings in clusters on the higher



Alteration of site topography should include measures to control water runoff. Slopes can be protected by using ground cover, retaining walls, terraces, and channels to direct the flow of water.

parts of the site, leaving the more vulnerable areas open. (See box.) This approach not only reduces direct flood damage but also allows greater flexibility in protecting the natural features on the site and controlling water runoff.

Large open areas can be used in a number of ways, depending on the nature of the project. They can be retained as agricultural or conservation preserves or developed as low-intensity recreation areas. Smaller parcels also have conservation and recreation potential, and can be effective buffers between conflicting land uses. With any of these uses, open space can serve as an amenity that enhances the value of developed property. Another alternative is to develop open areas as parking or temporary storage for transportable goods.

Restructuring Topography. On some sites it may be possible to use fill material—from either on-site or off-site—to create locations for buildings that are above the base flood elevation and meet other development criteria. This method would be aimed at the same objectives as described above, only being used where it will not increase flood levels due to displacement. Site restructuring also can be used to improve drainage and control runoff.

Special consideration should be given to soil conditions and slope stability, as well as flood water velocities and duration, to ensure that erosion does not add to flooding problems and endanger the structural integrity

Even when buildings are above flood levels, the improper location of streets can result in blocked access routes and damage to vehicles.

Philip Schmidt, Department of Housing and Urban Development of the building. When restructuring topography, exposed cut and fill slopes, as well as borrow and stockpile areas areas, should be protected. Runoff should be diverted from the face of slopes, and slopes should be stabilized with ground cover or retaining walls.

Circulation and Access. Every site must connect with a road system for access to the surrounding infrastructure, and larger development projects require circulation within the site. The objective in site design is to meet the program needs for circulation and access while maintaining safe access during flooding and avoiding damage to natural features that aid in the control of runoff and flooding.

Roads should be minimized to reduce the amount of surface paving. Site layout should locate roads to approach buildings from the direction away from the floodplain so that access routes will be less likely to be blocked by the flow of flood waters and debris. This approach will protect natural features in the floodplain and will minimize obstruction of the floodway. To reduce potential erosion, siltation, and runoff problems, roads should not disrupt drainage patterns, and road crossings should be perpendicular to streams, with adequate bridge openings and culverts to permit the unimpeded flow of water. If roads are to be raised, the slope of embankments should be minimized and open faces stabilized with ground cover or terracing.

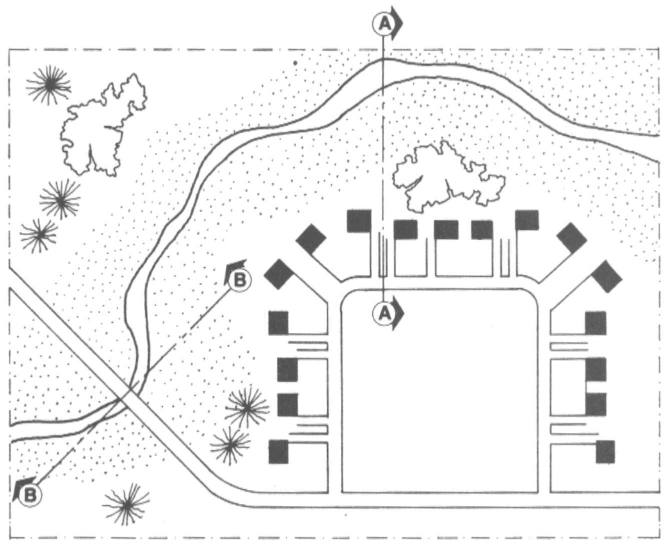
Control of Storm Water Runoff

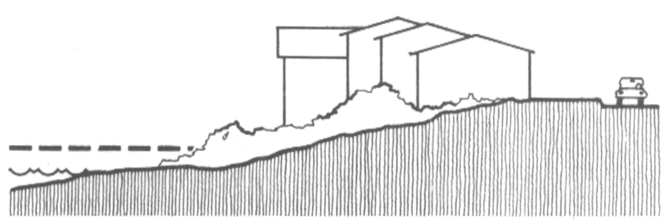
Water enters a given site either from precipitation or as runoff from upstream portions of the watershed. What happens to this water is a major determinant of both the degree of flooding and the potential of damage from flooding. If, through development of a site, there is an increase in the volume or velocity of storm water runoff, there will be an increase in flooding levels. Thus, as an ideal, runoff rates after development should not exceed the rates before development. This ideal may not always be possible or practical and may not be required by regulations, but should remain the objective of good site planning and design.

Site design techniques should work to protect the individual site, as well as minimizing increased flood levels elsewhere. There are a number of key factors that influence storm water runoff, and the combination of these must be considered in the site design process.

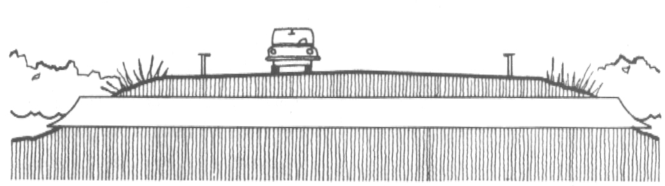
Soils. Soil porosity is one component in controlling water runoff. Soil composition needs to be firm enough to adequately support buildings but at the same time permeable enough to allow percolation of water to recharge the water table and to allow water to drain away from buildings. Balanced soil composition slows water runoff, increases infiltration, and helps prevent the build-up of

Streets should be located to approach buildings from the direction away from the floodplain so that access is less likely to be blocked and vehicles are not damaged by flood water. Road crossings should be perpendicular to streams, with adequate culverts or bridge openings to permit unimpeded flow of water.



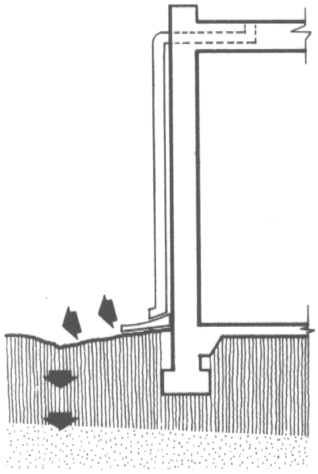


Section AA



Section BB

Water runoff should be routed away from the building's foundation before being allowed to percolate into the subsoil and water table.



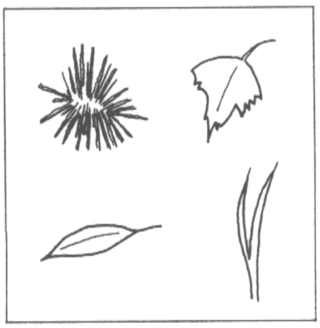
extreme water pressure on foundation walls, footings, and floors.

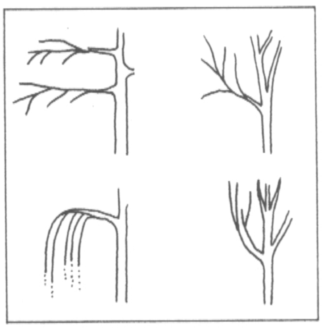
The type of soil on the site dictates the appropriate response for site development. Soils that remain saturated with water tend to corrode foundations. Heavy clay soils require the addition of sand to improve their drainage, the provision of good surface drainage, or a bed of gravel between soil and foundation to prevent foundation corrosion. Sand and silt, though porous, are unsuitable for stable foundations. They necessitate pilings to anchor the structure to deeper bearing soil.

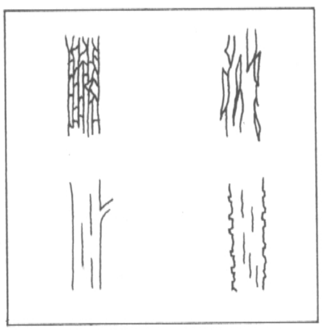
Vegetation. Vegetation aids in slowing the rate of storm water runoff by holding water, both internally and externally, thus allowing it to filter into the ground or evaporate gradually. In addition, vegetation makes an important contribution by helping to prevent erosion and sedimentation that exacerbate flooding.

Attention should focus on retaining natural vegetation wherever practicable, and on introducing planting in locations that will be most affected by runoff. The selection of plants should emphasize compatibility with natural conditions and the ability to hold the maximum amount of water. Leaf type, branching characteristics, and the texture of bark all affect water-holding capacity. A fibrous root structure can help control erosion.

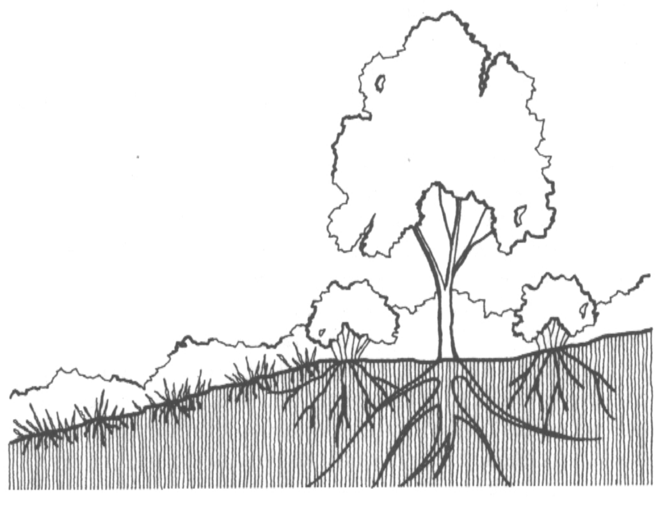
Dune Stabilization. Protection of the dune structure is a vital part of flood damage reduction in coastal areas. Dunes should be preserved in order to fulfill their role in maintaining the balance of the coastal ecosystem. In addition to keeping all buildings off dunes, natural vegetation should be retained to stabilize the dunes' sandy composition. Dunes should not be cut or breached by site development features such as walkways. The construction of jetties, groins, and similar structures should likewise be carefully controlled to prevent disturbance of the







Vegetation is useful in controlling runoff and stabilizing slopes. Foliage and roots hold water and prevent erosion. Plant leaves vary in their ability to hold water. Horizontal branching is most effective in preventing water runoff down the tree truck and erosion at the base of the tree. Rough bark holds and slows water running down the tree trunk and prevents erosion at the base of the tree.



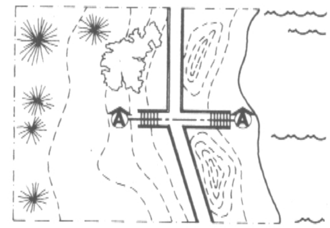
natural balance of the beach and dune system.

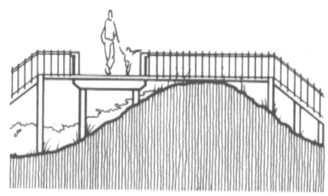
Impervious Surfaces. Nonporous surfaces contribute to the volume and velocity of water runoff, adding to the level of flood waters and increasing the chance of flash flooding. This is especially important on steep slopes and in the urban environment, where a large proportion of the surface has already been covered by buildings, streets, and parking areas.

Site design should maximize the preservation of open space and vegetation and avoid large continuous expanses of impervious surfaces. Large parking areas should be punctuated with planting. Streets, walkways, and parking areas should be constructed of porous paving materials wherever possible. Gravel, for instance, is highly porous, and bricks and flagstones can allow infiltration between joints. When soil conditions vary on the site, buildings should be located on the less porous soils, leaving areas with better filtration as open space.

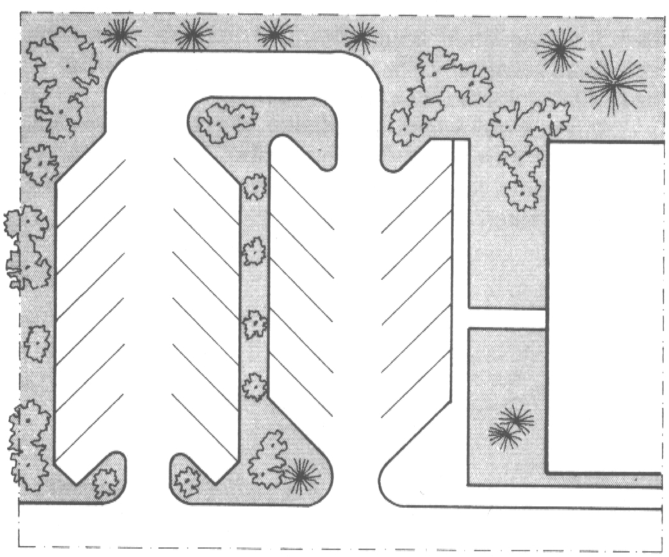
Water Storage. Water storage can be either temporary or permanent, depending on local ground water supplies, geology, and climate. Temporary storage can take a variety of forms, including the preservation of natural surface depressions in the landscape. Such "dry pond" storage helps to detain water after a storm, with gradual drainage, percolation, and evaporation to reduce the volume and velocity of runoff. This technique also helps replenish ground water supplies and can boost property values by increasing the site amenity and providing recreation space.

Temporary water storage can also be designed into parking areas by creating depressions in paved surfaces that, in combination with drainage channels, allow gradual runoff. In some situations large expanses of flat roof





Dunes should not be cut by site-development structures. Access to beaches can be provided by catwalks, stairs, and ramps that protect the fragile composition of the dune system.



Large expanses of nonporous surfaces, such as those used for parking lots, increase runoff. Parking areas should be designed to minimize impervious surfaces, using vegetation to maintain or improve natural drainage characteristics.

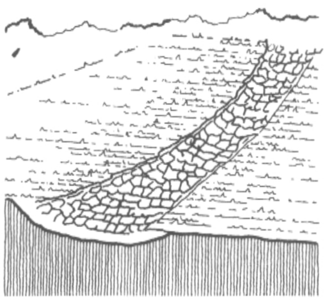
can be used to detain water, but this requires special attention to the roof's structural ability to support the weight of collected water and reliable waterproofing measures. Both of these methods can be helpful in offsetting the effects of existing impervious surfaces in urban areas where there is little open space to absorb runoff.

Permanent water storage in the form of ponds or lakes can be used in circumstances where a consistent supply of water and sufficient space exist. Ponds and lakes can add to site amenity and offer added potential for recreation and conservation habitats, though they do require regular maintenance.

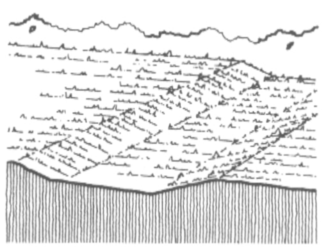
Open Channels. Open channels can serve as both small-scale storage devices and a means of directing runoff away from vulnerable areas. Their primary purposes are to divert water away from areas likely to erode, such as large, gently sloping areas and shorter steep slopes, and to collect and transport water runoff to larger drainage courses. Channels with grass cover are appropriate where the channel gradient is low; they can serve as percolation trenchs by allowing gradual infiltration while water is being transported. Linings are necessary in channels where vegetation cannot be established because flow is of long duration, runoff velocities are high, erodable soils exist, or slopes are steep. Concrete and asphalt paving or riprap are the most commonly used channel linings. However, such linings can increase the velocity of runoff, and thus should be designed with velocity checks to control the rate of water flow.

Streets and Curbs. Streets and curbs are frequently added during development, and the layout and gradient should be designed to complement runoff control systems. Streets, by decreasing the area of permeable surface, can create excessive runoff and contribute to localized flash flooding. Their design should avoid these problems, and should work to collect and convey water runoff at controlled velocities and to safe outlet points.

Storm Sewer System. Installation of a storm sewer system is often part of site development in large projects, usually parallel to the street and curb system. Storm sewers should interconnect with other drainage devices to

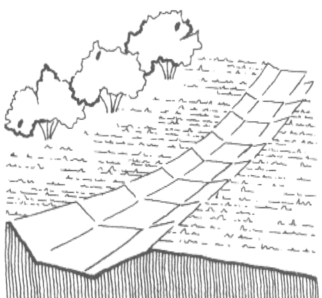


Riprap Channel.

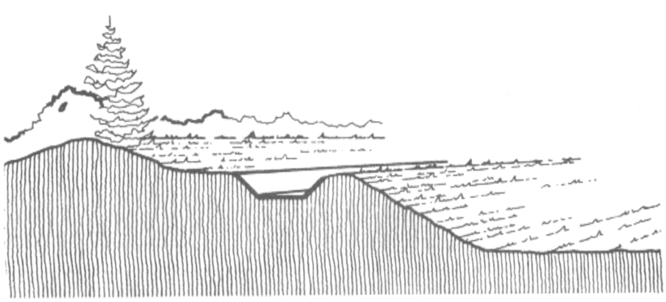


Grass-Lined Channel.

Open channels can be used to divert runoff around the face of vulnerable slopes and to direct the flow to larger drainage courses. Various linings can be used depending on the steepness of the channel. Porous linings offer the advantage of allowing gradual infiltration while water is being transported.



Concrete Channel.



Channel running across the slope to divert water.

Case Summary: Kiawah Island, South Carolina

Developer and Planner:
Kiawah Beach Company
Charleston, South Carolina

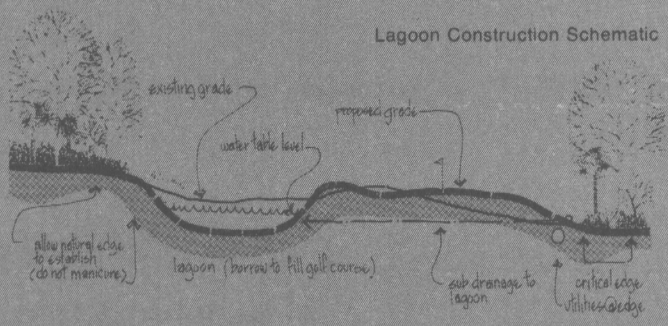
Kiawah Island, located 24 miles southwest of Charleston, South Carolina, is one of the many barrier islands found between North Carolina's Outer Banks and Northern Florida. Approximately 10 miles long and 3 miles wide, the island has 4100 acres of ground 3 feet or more above mean sea level. It consists of 11 miles of beach-front shoreline, dune ridges, salt marshes, tidal ponds, and forest vegetation.

The Kiawah Beach Company has proposed a planned development district on the island, using the 4100 acres as a residential resort community with a broad range of recreational opportunities and support activities. Planning for the project has included extensive analysis of the site's natural environment and careful consideration of how it can be accommodated as the land is developed.

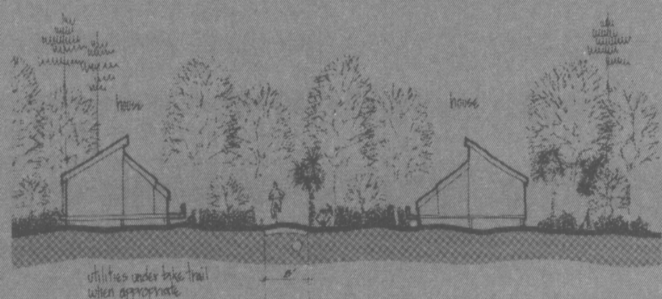
Site analysis encompassed detailed examination of existing environmental features, geologic processes, climate, hydrology, soils, and vegetation. From the analysis, planners concluded that "the susceptibility to flood is perhaps the single most important hazard to coastal development." In response, the development plan included the following flood-related elements.

- The expected flood elevations resulting from 25-, 50-, and 100-year storms, as determined by the National Oceanic and Atmospheric Administration, were mapped. To qualify for the National Flood Insurance Program, Charleston County has adopted the 100-year flood level as the minimum flood elevation for all new buildings and has established 6.5 feet above mean sea level as the minimum for any road.

Lagoon Construction Schematic



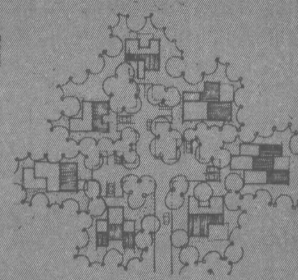
A system of lagoons will be constructed to complement the island's natural drainage system. These will retain storm water, allowing gradual runoff and percolation.



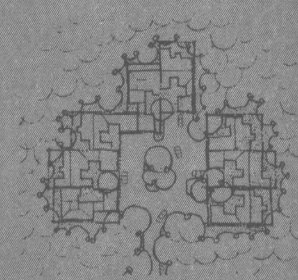
Buildings will be elevated where necessary to ensure that the lowest floor level is above the regulatory base flood elevation.

All proposed Kiawah Island development will conform to these standards.

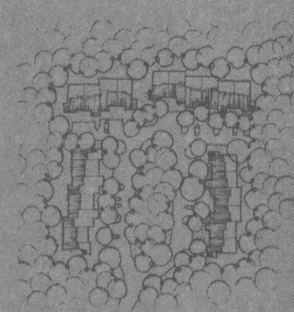
- Because the average annual rainfall for Kiawah is 49 inches it is important to have an adequate storm drainage system. The existing topography lends itself to the development of a good natural drainage system. The island is penetrated by a series of low areas that can be readily developed into an efficient network of lagoons. These will handle storm water runoff from adjacent higher areas as well as store water until it can be released gradually into the surrounding waters. The use of existing low areas allows the lagoons to be developed with minimum earthwork and thus with the least possible damage to the adjacent vegetation. The absence of deep cuts and steep banks also reduces the potential for erosion. The excavated material can be used for nearby building sites and recreation facilities and the completed lagoons will provide added site amenity.
- The success of the storm drainage system is not solely determined by the engineered structures. The protection of natural ground covers, trees, and shrubs, in combination with the sandy soils, provides for natural percolation of runoff into the ground water table.
- The most predominant land use on the island will be residential. The land use plan encourages clustering of residences to achieve construction and land economies but, of equal importance, restricts disturbance of natural areas and hence minimizes erosion and consequent flooding potential.



Detached single family cluster.



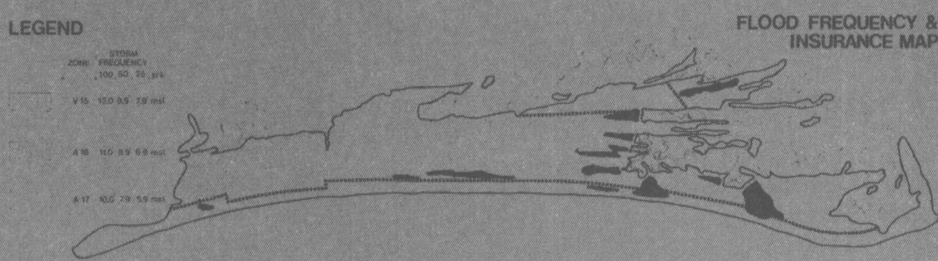
Attached single family cluster.



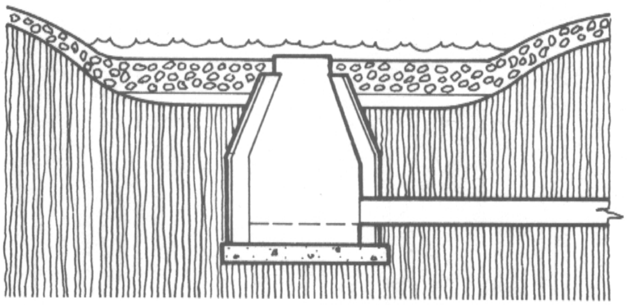
Townhouse cluster.

The land use plan relies on clustering to achieve construction and land economies and to reduce the potential of erosion, excessive runoff and flooding. Shown are three examples of how dwellings can be clustered.

FLOOD FREQUENCY & INSURANCE MAP



Expected flood frequencies were mapped for the project and development proposals were designed to conform with all flood-related regulations.



Sediment traps, installed at storm sewer inlets, help prevent sediment deposits and maintain the steady drainage of storm water.

decrease the velocity of storm water runoff and to release water at controlled points and rates of flow. Lines and access points need to be sized and distributed to accommodate the runoff likely to be associated with the site and not cause backup of water and the resulting overspill of flash flooding. The capacity of the storm sewer system can be impaired by sediment deposits within the systems; to avert this problem, drain inlets should be designed with sediment traps and filters.

Building Design Techniques

In the design of buildings that must be located in a flood hazard area, several problems should be addressed in reducing the threat of flood damage. These include:

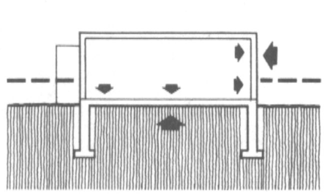
- Entrance of water through building openings
- Damage to building finishes and contents
- Seepage through walls, floors, and foundations
- Water pressure on foundations, walls, and floor slabs
- Back-up of water through sewer systems
- Access to and from buildings during floods.

To deal with these problems adequately the designer can incorporate a variety of flood damage reduction techniques in building design. These techniques interact with site design features and, as with site design, the techniques used for any given project will vary with individual circumstances, needs, and resources.

Floodproofing. The term floodproofing is used here to describe any method of making buildings resistant to flood damage. Floodproofing strategies are particularly appropriate where moderate flooding (i.e., low flood stage, low velocities and short duration) is likely, or where buildings' uses require riverine or coastal locations. The principal approach to achieving this objective is to protect buildings from water by keeping their interiors dry during flooding. This can involve raising buildings above flood levels or waterproofing the portions of the building that are below flood levels.

Keeping flood water out of buildings requires special structural support. During flooding, water entering the building serves to equalize water pressure that builds up on the exterior. If this equalization is eliminated by waterproofing, then the building is likely to collapse. If a strategy is adopted that keeps water out, then the building must also be made structurally capable of withstanding these exterior water pressures.

Flooding causes the build-up of exterior water pressure, which must be equalized to avoid major structural damage to buildings located in flood-prone areas.



The "dry" floodproofing approach, as described above, is the most common and widely applicable way to protect buildings and their contents from flood damage. An alternative that can be used in some situations is "wet" floodproofing, which involves purposely allowing water to flow into a building when flood levels rise, thereby equalizing water pressures and avoiding major structural

Benefit/Cost Analysis

Studies published by the Federal Emergency Management Agency indicate that floodproofing buildings in both riverine and coastal environments can be cost effective. One study analyzed four different flood damage reduction strategies, as applied to a small commercial building.* The four methods tested were:

- Wet Floodproofing
- Elevating the building on fill material
- Partially elevating the building on fill and equipping it with watertight closures
- Elevating the building on columns

Analysis found that wet floodproofing was not economically justifiable in this case study, but that all three dry floodproofing techniques were cost effective. Elevating the prototype building on fill was most favorable, with benefit/cost ratios of 5.96 for reduction of insurance premiums (see below) and 3.46 for reduction of flood losses.

In another study the costs and benefits of elevating a 2500-square-foot model house in a coastal high hazard area were analyzed. The study concluded that,

> In high hazard areas of the Atlantic and Gulf of Mexico coasts, new homes elevated to the wave crest level associated with 100-year storm surge are economical for individual homeowners, both in terms of reduced flood losses and of reduced insurance premiums.**

Three techniques for elevating the house were analyzed, and one, the use of a rigid frame design, proved to be most advantageous. It was least expensive, had the highest safety factor, and the highest benefit/cost ratios for reduction of both flood losses (between 3.1 and 8.2) and flood insurance premiums (between 5.9 and 9.5).

Unquestionably, the most effective means of reducing flood losses is to locate out of flood hazard areas. However, where this is not possible, floodproofing alternatives should be explored. As noted above, the added costs of floodproofing can be offset by reduced flood insurance premiums and reduced flood losses over the life of the structure.

Reduced Insurance Premiums. Actuarial rates for insurance premiums are keyed to elevation above or below the base flood elevation (BFE), and according to risk zones. For example, if a one-to-four family house is being built in flood risk zones A8 to A14, the flood insurance premium can vary as follows.

- $0.10 per $1000 coverage when the first floor elevation is three feet **above** the BFE
- $1.60 per $1000 coverage when the first floor elevation is **equivalent to** the BFE (the minimum standard)
- $9.30 per $1000 coverage when the first floor elevation is three feet **below** the BFE.

Thus it is clear that the cost savings to the client can be significant, even with only a three-foot increase over the minimum standard. In view of both the cost savings and the added margin of safety in the extra elevation, the designer should work with the client to elevate above the minimum level wherever possible.

Benefit/Cost Ratios:

Alternative methods of Coastal Construction; Gulf Shores, Alabama

Wave Crest Elevation (Feet)	18	17	16	15	14
Storm Surge Elevation (Feet)	11	11	11	11	11
Difference (Feet Below Wave Crest Elevation)	−7	−6	−5	−4	−3
Benefits derived from reduced average annual flood damage					
Rigid Frame System	74.9	9.5	16.6	8.2	5.9
Semi-Rigid Frame System With Grade Beam (Czerniak Method)	33.2	4.1	4.1	2.8	1.8
Semi-Rigid Frame System With Grade Beam (Griffith Method)	24.5	3.0	3.3	2.2	1.4
Benefits derived from reduced flood insurance premiums					
Rigid Frame System	8.2	6.2	6.2	4.5	3.1
Semi-Rigid Frame System With Grade Beam (Czerniak Method)	3.6	2.7	2.2	1.5	1.0
Semi-Rigid Frame System With Grade Beam (Griffith Method)	2.7	1.9	1.8	1.2	0.9

Benefit/Cost:

Alternative Floodproofing Methods for a Small Commercial Building; Jersey Shore, Pennsylvania

	No Floodproofing	Wet Floodproofing	Raised on Fill	Partially Raised with Watertight Closures	Raised on Columns
Floodproofing Benefits Derived from Reduced Annual Flood Losses	0	0.25	3.46	1.39	1.53
Floodproofing Benefits Derived from Reduced Insurance Costs	—	—	5.96	2.31	2.48

*Sheaffer and Roland, Inc., *Economic Feasibility of Floodproofing: Analysis of a Commercial Building* (Washington, D.C.: Federal Emergency Management Agency, 1979) pp. 18-23.

**Sheaffer and Roland, Inc., *Elevating to the Wave Crest Level: A Benefit/Cost Analysis* (Washington, D.C.: Federal Emergency Management Agency, 1980) pp. 34-47.

Case Summary: Naval Submarine Support Base Kings Bay, Georgia

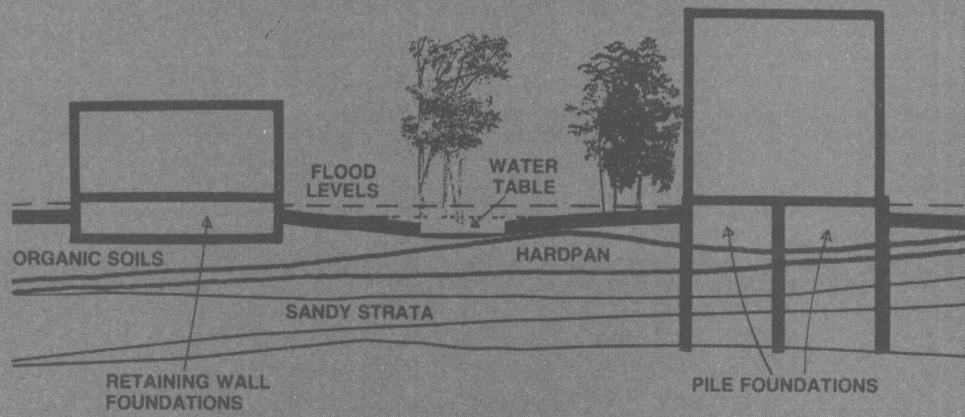
Planning and Design:
Zimmerman, Evans and Leopold, Inc.
Atlanta, Georgia

AECK Associates, Inc.
Atlanta, Georgia

This project called for developing a complete master plan for a 12,000-acre submarine support base for the U.S. Navy. The plan, which is structured to maintain maximum flexibility within designated land use areas, will be used by the Navy to establish broad planning and design policies for the base and to guide program implementation.

One of five functional areas in the plan is the Personnel Support Area. It includes military housing, a recreation complex, administration and training facilities, and related commercial facilities. Site planning concepts were developed to respond to the unique constraints of the site. This included planning for land areas inside the 100-year flood boundary. Specific guidelines relating to flood damage reduction include:

- Buildings will be elevated to minimize the impact on existing drainage systems.
- Buildings will be elevated above the 100-year flood levels.
- Pedestrian walkways will be elevated on timber or concrete piles to protect environmentally sensitive coastal areas.



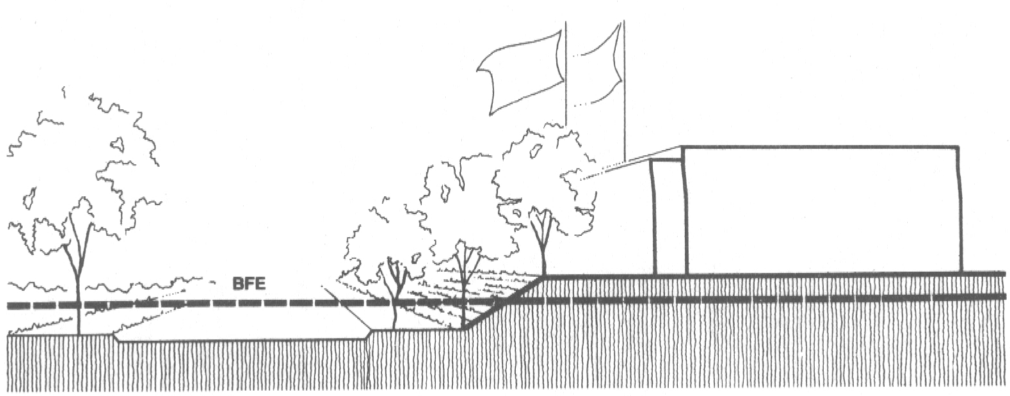
Buildings are to be elevated to reduce flood damage and to minimize the effects on the existing natural environment.

damage. This technique also focuses on minimizing damage to the interior of the building when water does enter.

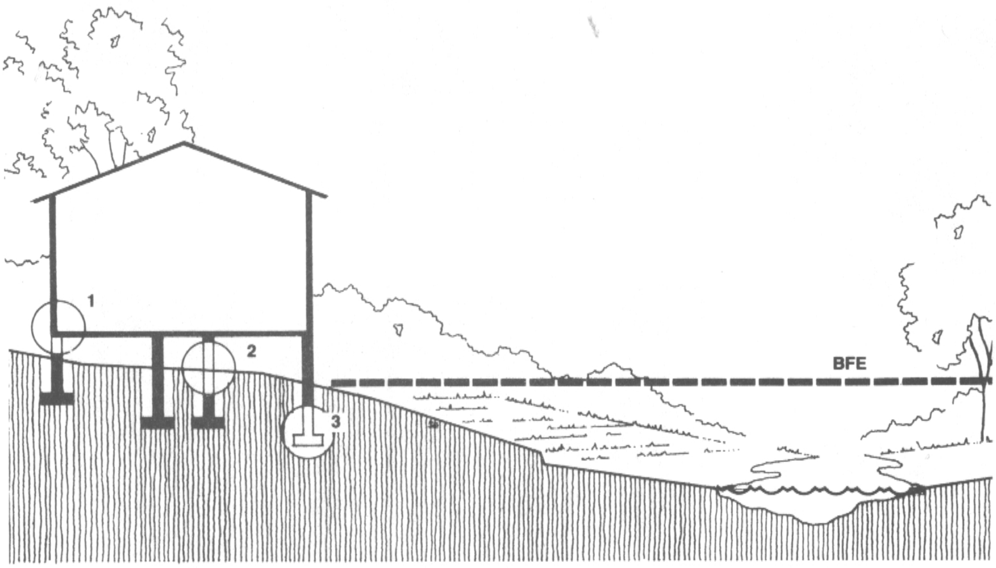
The following discussion of specific techniques assumes adoption of the dry floodproofing approach to mitigating flood damage. Wet floodproofing is discussed after the other methods as a separate technique.

Elevating Buildings. Elevating buildings above the base flood level is a common technique for reducing flood damage. Flood insurance requirements mandate that residential buildings in flood-prone areas be elevated and that other types of buildings be elevated and/or floodproofed. It is a particularly useful technique where site elevations are consistently below the base flood elevation, and offers the greatest assurance of keeping a building dry during flooding.

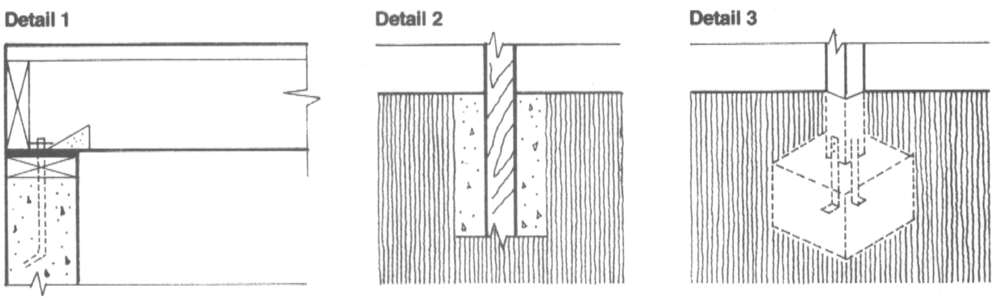
One method of raising buildings is to use fill material to achieve the desired elevations. This technique interacts with the various site design issues, and requires consideration of the type of fill, compaction and settlement of fill, protection against erosion, and the effect of



Buildings can be raised above the BFE by the use of fill material.



Buildings can be raised above the BFE on posts, piers, or columns. They must be securely anchored to the stilts, which in turn must be anchored to footings. Stilts should be secured in the ground by backfilling.



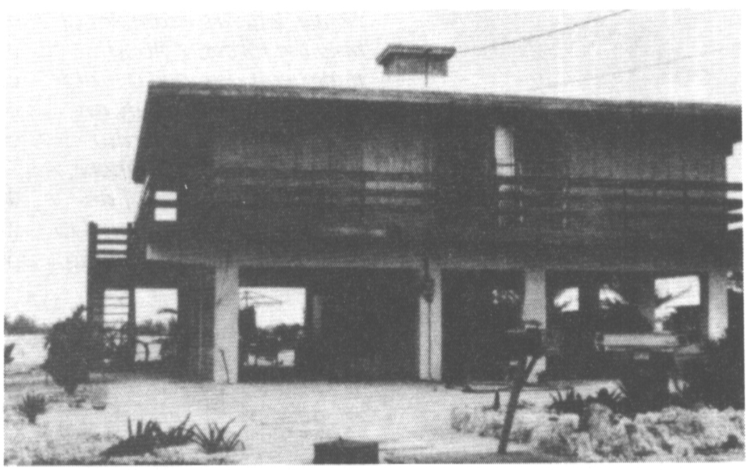
altered land forms on the flooding levels elsewhere in the watershed system.

Another approach to elevating buildings is to raise them on some form of stilts, such as piers, posts, or columns. This method puts the building above the base flood level and leaves the ground level predominantly open. The open ground offers the advantage of not impeding the flow of flood water or displacing a significant volume of water, thus being less likely to increase downstream or upstream flood levels.

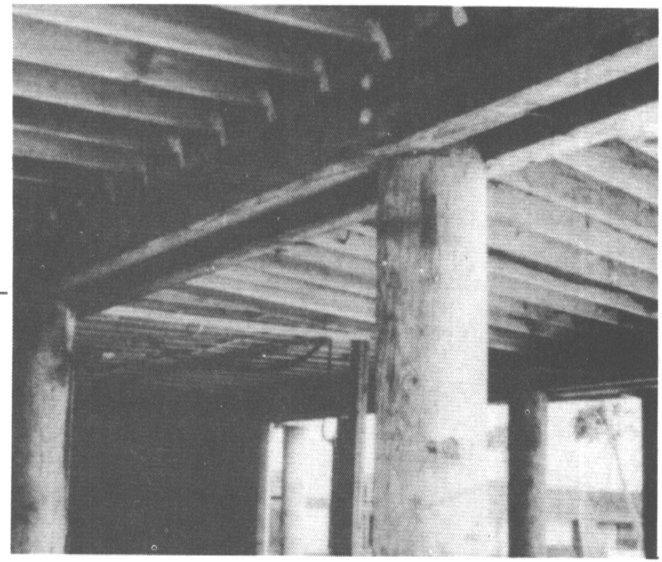
In using stilts, the designer must consider the size and spacing of stilts to ensure adequate support with minimum obstruction. Stilts should penetrate to bearing soil and be firmly anchored to ensure that they will be able to resist vertical and horizontal water pressure and debris impact loads.

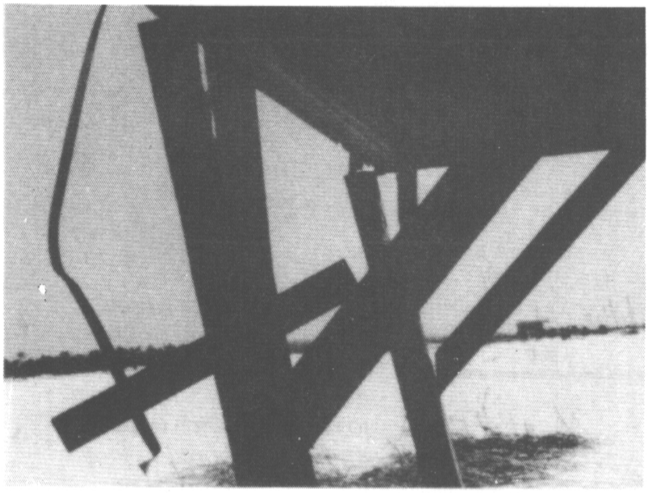
Extended foundation walls can also be used to elevate buildings above flood levels. However, the vertical surfaces of walls can obstruct the flow of water and are

This beach house has been elevated on concrete piers to minimize flood damage.

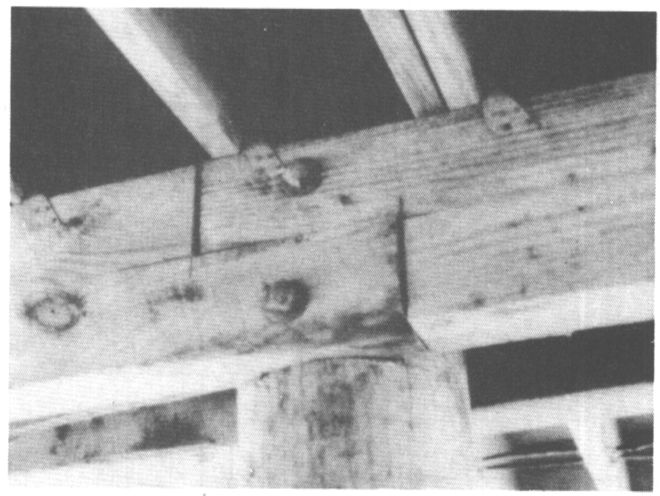


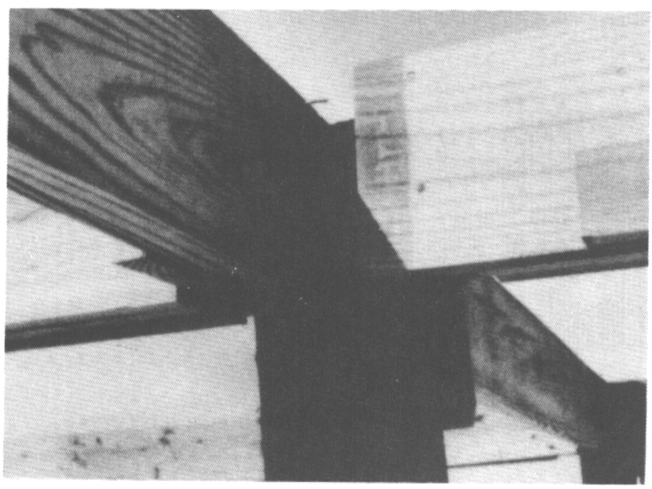
Department of Housing and Urban Development





Raymond R. Fox, Dames and Moore





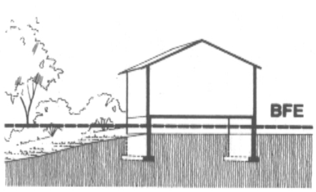
subject to greater lateral water pressure. Longer walls should be located parallel to the flow of flood water to minimize these dangers. All foundation walls that might be subjected to flooding should be anchored to prevent displacement or flotation.

In some cases it can be advantageous to use a combination of methods. For example, a building can be raised on fill at one end and on stilts at the other. This would be beneficial in providing ground floor access at the end of the building that is away from the floodplain while minimizing obstruction of water at the end nearer the stream channel. Techniques for elevating buildings can also be combined with waterproofing techniques in some circumstances.

In using any of the methods for elevating a structure, the designer must consider access to and from the building during flooding and the protection of utility lines and points of entry.

Spatial Organization. The internal spaces of buildings located in or partially in a floodplain should be organized to minimize damage in the event of inundation. The most vulnerable elements of the building should be located above flooding levels. This would typically include placing all mechanical equipment on the upper floors or roof of the building. Depending on the respec-

Above, left, are examples of how the forces of flood water can damage a building if it is not securely anchored to piers, foundations, and footings. Above, right, are examples of anchoring systems designed to resist the forces of flooding.

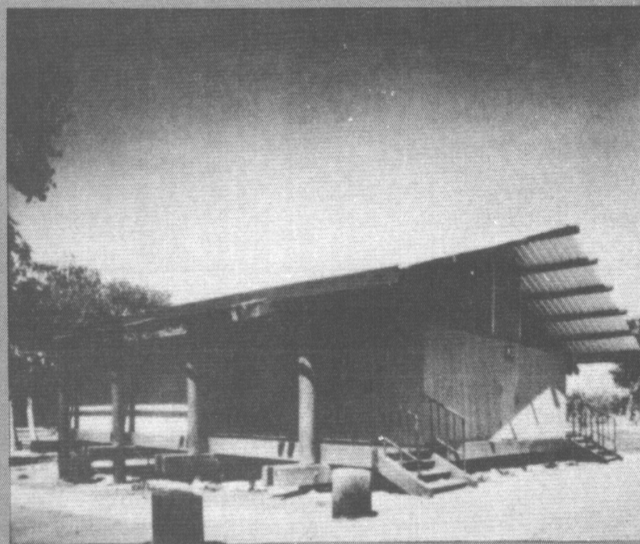


Buildings can be elevated on extended foundation walls. Vertical walls should be sited to minimize obstruction of water flow during flooding.

Case Summary: Featherly Regional Park Orange County, California

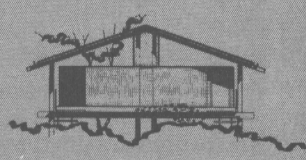
Designer:
Dan L. Roland and Associates
Anaheim, California

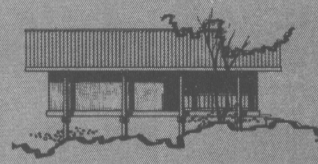
Featherly Regional Park is a 156-acre facility located in Orange County, California. The park is traversed by the Santa Ana River, which flows throughout the year. The majority of the park site is subject to flooding during the rainy season. The purpose of the project was to provide camping and picnicking areas as well as administration, concession, and toilet facilities. The design solution included elevation of permanent buildings on poles. This minimized soil disturbance, preserved existing vegetation important in reducing soil erosion, and reduced the effects of flood damage to the buildings.



Dan L. Roland and Associates

Support facilities for the park were designed to be elevated on posts to minimize their impact on the natural environment and to reduce the effects of seasonal flood damage.





tive elevations, machinery and similar equipment should be raised off the floor or anchored to prevent flotation. Particularly valuable and vulnerable contents, such as computer equipment, should be located in areas above flood levels or otherwise securely protected from inundation (e.g., raised on stilts or surrounded by a waterproof enclosure). Spatial configuration should also allow for access to, from, and within the building during flooding.

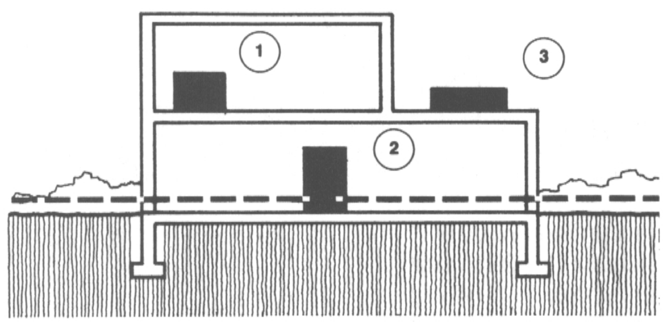
Elimination or Protection of Openings. The most vulnerable components of the basic building fabric are the points where walls below flood levels are penetrated. These points include doors and windows, as well as utility inlets and, in some cases, underground tunnels to adjacent buildings. Such points should be either located above flood levels or thoroughly waterproofed.

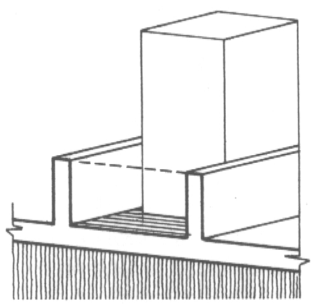
Ideally, all doors and windows should be above the base flood elevation, with access provided via ramps, stairs, or fill. Rubber gaskets can sometimes be used to seal openings below the base flood elevation, and waterproof conduits can be used to protect utility lines.

Openings for doors and windows unavoidably located below flood levels can be protected by flood shields that would be put in place upon receipt of flood warnings. These shields can cover openings ranging from small areas to large display windows. They can sometimes be incorporated in the building's structure, out of the way when not needed and, using hinges and rollers, put in place when necessary. They can also be separate from the structure and stored when not in use. Adequate warning time is a prerequisite to the effectiveness of shields.

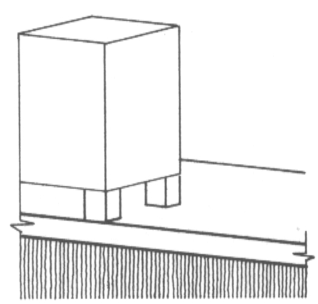
Openings below the base flood elevation in existing buildings can often be eliminated, with alternative entry points provided at higher levels. Windows below flood level can sometimes be replaced by glass bricks, which al-

The internal configuration of buildings in flood-prone areas must be organized to minimize damage to contents in the event of flooding. Computers, financial records, and other vulnerable contents (1) should be placed on upper floors. Mechanical equipment (2) should be located on upper floors or on the roof. Machinery or other contents that must be in vulnerable locations (3) should be protected, either by surrounding it with a watertight enclosure (3A) or raising it above flooding levels (3B).

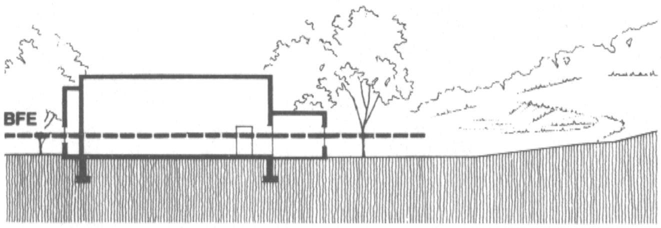


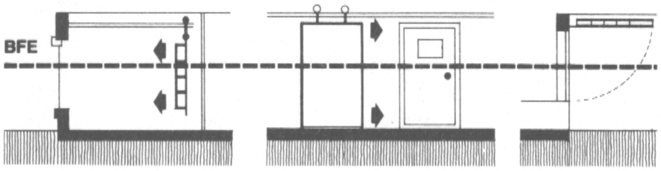


Detail 3A

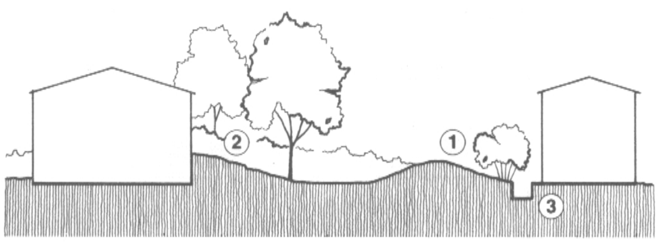


Detail 3B





Doors and windows below the BFE can be protected by flood shields that can be put into place on receipt of flood warnings. The examples below use rollers and/or hinges.



On-site flood control measures, such as earth berms, can be used to protect buildings from flooding. They can be free standing (1) or directly against the building (2). When berms or other types of flood walls are used it is important to install sump pumps (3) to ensure that dry conditions are maintained within the enclosure.

low light but can withstand moderate amounts of water pressure during flooding.

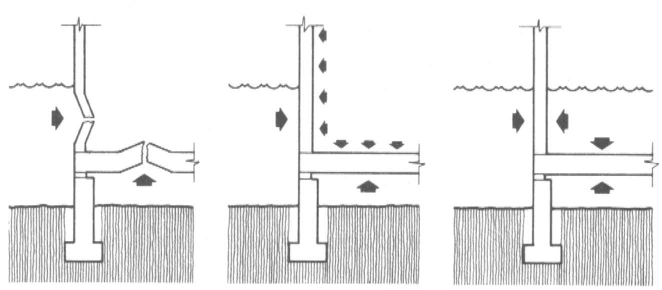
On-Site Flood Control. Levees and retaining walls can be used as on-site flood control measures to keep water away from all or part of a building. These can be in the form of earth berms—either free-standing or directly against the building—which can also provide access routes. Retaining walls can be incorporated into buildings as fences or patio enclosures to protect openings that are below the base flood level, and provide privacy and amenity as well.

Such control measures should be designed to resist lateral and vertical water pressures, protect against erosion, and not obstruct the flow of water.

Enclosures designed to protect openings should be combined with sump pumps to ensure that dry conditions are maintained within the protected area. Emergency power supplies should always be available for operating the pump during storms, when normal power is likely to be disrupted. Levees and walls can be combined with flood shields to maximize their effectiveness, and can be appropriate for any size or type of building. Their use should be carefully coordinated with site design issues.

Building Materials. Even when using "dry" floodproofing approaches to reducing flood damage, some parts of a building may be exposed to water. If so, water-resistant building materials should be used. This could include the use of water-resistant lumber, floor coverings, adhesives, and paints, as well as masonry construction and finishes, and waterproof mechanical and electrical fittings. The use of water-absorbent materials such as gypsum board paneling should be avoided below flood levels.

Structural Walls. All structural walls should be designed to accommodate hydrostatic, hydrodynamic, and debris impact loads. The walls should be able to withstand the lateral forces from the predicted depth and velocity of flood waters, as well as the vertical forces from flood waters and rising ground water levels, which require secure anchoring to footings and foundations. Potential seepage requires the use of sealants, external wall coatings, and the secure joining of walls, floors, and foundations.



Water pressure caused by flooding affects both vertical and horizontal structural members. This pressure must be countered, either by structural reinforcing or by allowing an equivalent amount of water into the structure, to avoid major structural damage.

Floors. Floors should be designed to withstand the vertical pressures associated with flooding. This requires consideration of soil composition and ground water levels, as well as the likely flood levels in relation to building elevations. Floor design should provide adequate thickness and reinforcing to resist water pressure, and can include the provision of extra weight (e.g., concrete pads) to prevent flotation. Floors should be securely anchored to foundations, and joints between walls and floors should be securely tied and sealed to prevent displacement or seepage.

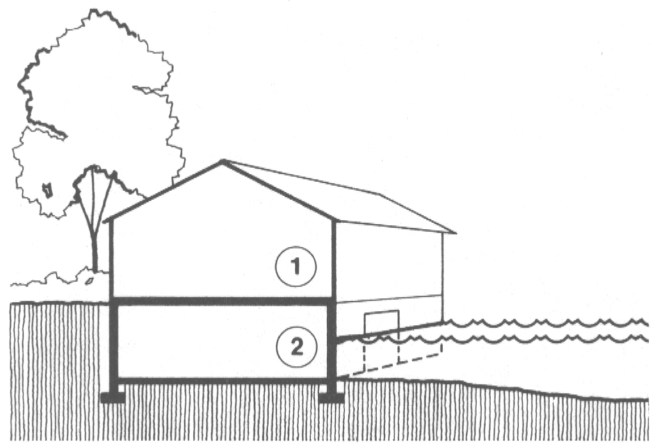
Footings and Foundations. Footings and foundations require special consideration in flood-prone areas. They should be at a sufficient depth and on bearing soil in order to provide the necessary lateral resistance to water pressure, and should also be able to resist vertical pressures. In some cases this may require additional anchorage with pilings or extra weighting with concrete pads. Also necessary is the protection of footings and foundations from erosion and scour, which is especially important where they will be subjected to extreme velocities, such as with coastal tides and storm surges.

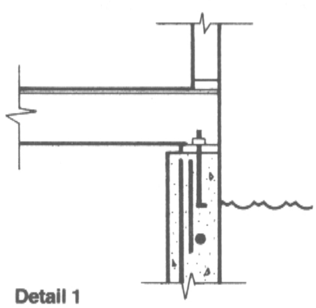
Utilities. All utility lines should either enter the building above the base flood elevation or be waterproofed and secured to prevent displacement due to water pressure. When a utility line enters the building below the base flood level, it should be routed so that the interior outlet point is above the flood level. Internal and external fittings that are below flood levels should be thoroughly waterproofed, and control panels should be above the base flood elevation to allow access during flooding. Controls for lower floors and basements can often be isolated to allow them to be disconnected independently during flooding.

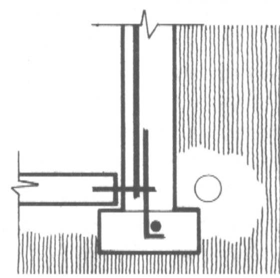
Mechanical Systems. All mechanical equipment and controls should be located above the base flood elevation to prevent damage and to allow access to the equipment during flooding. The duct work associated with the mechanical system should be elevated or otherwise protected from water damage.

Plumbing. Floor drains and other plumbing will often be unavoidably located below the base flood level. They should be fitted with valves to prevent the backflow of water that would damage the interior of the building. Sump pumps should be installed to remove small quantities of water, with the drain outlet of the pump located above the base flood level and an emergency power source available.

Wet Floodproofing. As mentioned earlier, wet floodproofing is a special technique that can be used under certain circumstances to reduce flood damage. The distinguishing characteristic of wet floodproofing is that rather than trying to keep water out, water is purposely intro-







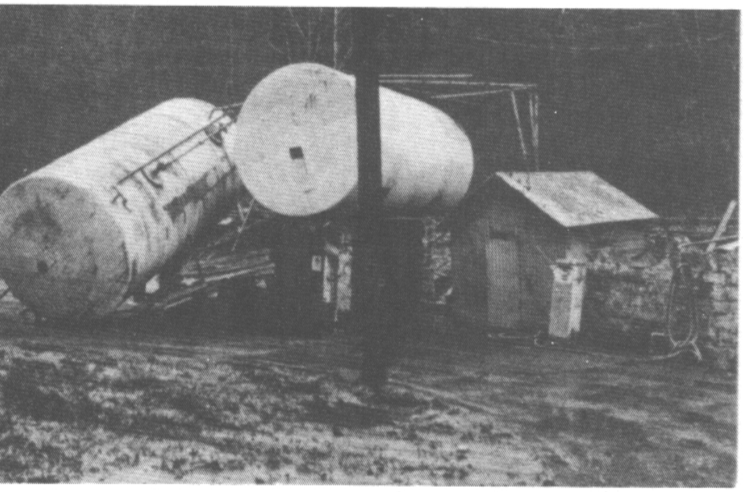
Secure connections between different parts of the building are necessary to prevent flood damage. The building must be firmly anchored to foundations (1) and foundations must be anchored to footings (2). The house below was not adequately anchored to its foundation.

Department of Housing and Urban Development duced into a building at times of flooding. This is done so that the water level inside will counteract the pressure of rising flood water on the outside, thus reducing the possibility of major structural damage. This technique is potentially useful where damage from exposure to water will be minimal and post-flood clean-up relatively easy.

Wet floodproofing requires that all parts of the building below the base flood level be constructed and fitted with water-resistant materials and finishes. Surfaces should be nonporous in order to minimize absorption and facilitate cleaning (e.g., concrete, metal, plastic, or glass). Pumping clean water in as flood waters rise, rather than allowing flood water to enter, will simplify clean-up. All interior spaces must be allowed to fill with water, including any cavity walls, and must be able to drain and be cleaned after the water recedes.

It is essential in wet floodproofing that utility and mechanical systems be accessible and operable before, during, and after flooding. Thus they must be either above the base flood elevation or waterproofed and anchored. Fuel and chemical storage tanks must be elevated or located on upper floors above flooding levels, or evacuated prior to flooding. Valves that maintain equalized water pressure and clean-up equipment must be included in a wet-floodproofed building.

The many special requirements of wet-floodproofing and its limited effectiveness in reducing damage to contents limit the number of situations to which it can be applied. However it could be useful in some industrial buildings and may be appropriate for limited-use basement areas that are below the base flood elevation.

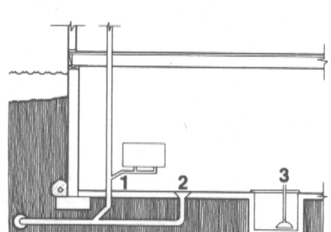


Department of Housing and Urban Development

All potentially damaging elements must be firmly anchored. Storage tanks can be damaged when torn from their mountings and can increase hazards if their contents are spilled or if they are carried away as debris.

The foregoing techniques are not all-encompassing, but indicate the design issues involved in reducing flood damage, ranging from site selection to control of storm water runoff and from building configuration to structural requirements. They are outlined to provide an overview of the general information needed and the tools that are available for design in flood-prone areas. More detailed information is available from the literature references cited and from the relevant government agencies listed in the Resource Index.

The designer with a firm grasp of these flood-related issues and techniques is better prepared to generate appropriate design responses for each specific project and site. Increased knowledge allows the designer to accept the creative challenge of designing to meet programmatic and aesthetic standards while simultaneously reducing flood losses throughout the natural and built environment. The designer is thus able to meet professional responsibilities while benefiting both the client and the community.



Plumbing drainage lines (1 and 2) should be fitted with valves to prevent the back-flow of flood water into the building. Sump pumps should be installed to remove small quantities of water that might build up, even in floodproofed buildings.

Heritage Conservation and Recreation Service

Literature Resources

Design and Construction Manual for Residential Buildings in Coastal High Hazard Areas. Dames & Moore, Inc. Washington, D.C.: U.S. Department of Housing and Urban Development; Federal Emergency Management Agency, Federal Insurance Administration, 1981.

Elevated Residential Structures: Reducing Flood Damage Through Building Design. AIA Research Corporation. Washington, D.C.: Federal Insurance Administration, 1976.

Earthscape: A Manual of Environmental Planning. John O. Simonds. New York: McGraw-Hill Book Company, 1978.

Flood Proofing Regulations. Washington, D.C.: U.S. Army, Office of the Chief of Engineers, 1972.

Introduction to Floodproofing. John R. Sheaffer. Chicago: Center for Urban Studies, University of Chicago, 1967.

Lakes and Ponds. Joachim Tourbier and Richard Westmacott. Washington, D.C.: Urban Land Institute, Technical Bulletin 72, 1976.

Manual for the Construction of Residential Basements in Non-Coastal Flood Environs. National Association of Home Builders Research Foundation, Inc. Washington, D.C.: Federal Insurance Administration, 1977.

Michigan Soil Erosion and Sedimentation Control Guidebook. Lansing, Michigan: Bureau of Water Management, Michigan Department of Natural Resources, n.d.

Residential Storm Water Management. New York, N.Y. and Washington, D.C.: American Society of Civil Engineers, National Association of Home Builders, and the Urban Land Institute, 1975.

The Role of Vegetation in Shoreline Management. Great Lakes Basin Commission. Chicago: U.S. Army Corps of Engineers, North Central Division.

Resource Index

Glossary

Actuarial Rates. Rates established by the Federal Insurance Administration pursuant to Flood Insurance Studies for individual communities. These rates are set in accordance with the National Flood Insurance Program (NFIP) and accepted actuarial principles. Subject to various other limitations, actuarial rates are applicable only after the publication and effective date of a community's Flood Insurance Rate Map (FIRM).

Base Flood Elevation (BFE). The elevation for which there is a one-percent chance in any given year that flood levels will equal or exceed it. The BFE is determined by statistical analysis of streamflow records for the watershed and rainfall and runoff characteristics in the general region of the watershed.

Coastal High Hazard Area. The portion of a coastal floodplain that is subject to high velocity waters caused by tropical storms, hurricanes, northeasters, or tsunamis. NFIP regulations for Coastal High Hazard Areas apply where tides, storm waves and surges, and local geographic characteristics combine to produce a breaking wave of three feet or more.

Debris Impact Loads. Loads induced on a structure by solid objects carried by flood water. Debris can include trees, lumber, displaced sections of structures, tanks, runaway boats, and chunks of ice. Debris impact loads are difficult to predict accurately, yet reasonable allowances must be made for them in the design of potentially affected structures.

Encroachment. Any physical object placed in a floodplain that hinders the passage of water or otherwise affects flood flows.

Existing Construction. Those structures already existing or on which construction or substantial improvement was started prior to the effective date of a community's floodplain management regulations.

First Floor. The floor that is level with or immediately above the main point of entry into the building. For residences, it is additionally that floor that comprises the main living area of the dwelling.

Flood or Flooding. A general and temporary condition of partial or complete inundation of normally dry land areas. Flooding results from the overflow of inland or tidal waters or the unusual and rapid accumulation of surface water runoff from any source.

Flood Fringe. The area within the floodplain (as determined by the reach of the one-percent-probability flood) that is outside the floodway.

Flood Hazard Boundary Map (FHBM). An official map of a community, issued or approved by the Federal Emergency Management Agency on which the boundaries of the floodplain and special flood hazard areas have been designated. This map is prepared according to the best flood data available at the time of its preparation, and is superseded by the Flood Insurance Rate Map after more detailed studies have been completed.

Flood Insurance Rate Map (FIRM). An official map of a community, issued or approved by the Federal Insurance Administration, that delineates both the special hazard areas and the risk premium zones applicable to the community.

Flood Insurance Study (FIS). A study, funded by the Federal Insurance Administration and carried out by any of a variety of agencies and consultants, to delineate the special flood hazard areas, base flood elevations, and NFIP actuarial insurance rate zones. The study is based on detailed site surveys and analysis of site-specific hydrologic characteristics.

Floodplain. Any normally dry land area that is susceptible to being inundated by water from any natural source. This area is usually low land adjacent to a river, stream, watercourse, ocean, or lake.

Floodplain Management. The operation of a program of corrective and preventive measures for reducing flood damage, including but not limited to flood control projects, floodplain land use regulations, floodproofing of buildings, and emergency preparedness plans.

Flood Profile. A graph showing the relationship of water surface elevation to a specific location, the latter generally expressed as distance above the mouth of a stream of water flowing in an open channel. It is generally drawn to show surface elevation for the crest of a specific magnitude of flooding, but may be prepared for conditions at any given time or stage.

Floodproofing. Any combination of structural provisions and/or other modifications incorporated into individual buildings or properties primarily for the purpose of reducing or eliminating flood damages.

American Red Cross

Floodway. The channel of a river or watercourse and the adjacent land areas that must be reserved to discharge the one-percent-probability flood without cumulatively increasing the water surface elevation more than a designated height, generally one foot.

Flood Boundary and Floodway Map. An official map of a community, issued or approved by the Federal Emergency Management Agency, on which floodplain and floodway boundaries have been designated.

Hydrograph. A graph that charts the passage of water as a function of time. It shows flood stages, depicted in feet above mean sea level or gage height, plotted against stated time intervals.

Hydrology. The science of the behavior of water in the atmosphere, on the earth's surface, and underground.

Hydrodynamic Loads. As flood water flows around a structure at moderate-to-high velocities it imposes loads on the structure. These loads consist of frontal impact by the mass of moving water against the structure, drag effect along the sides of the structure, and eddies or negative pressures on the structure's downstream side.

Hydrostatic Loads. Those loads or pressures resulting from the static mass of water at any point of flood water contact with a structure. They are equal in all directions and always act perpendicular to the surface on which they are applied. Hydrostatic loads can act vertically on structural members such as floors, decks, and roofs, and can act laterally on upright structural members such as walls, piers, and foundations.

Infiltration. The flow of fluid into a substance through pores or small openings. The word is commonly used to denote the flow of water into soil.

Mean Sea Level. The average height of the sea for all stages of the tide, usually determined from hourly height observations over a nineteen-year period on an open coast or in adjacent waters having free access to the sea.

New Construction. Structures on which construction or substantial improvement was started after the effective date of a community's floodplain management regulations.

One-Hundred-Year Flood. See Special Flood Hazard Areas.

Permeability. The property of soil or rock that allows passage of water through it.

Regulatory Floodway. Any floodway referenced in a floodplain ordinance for the purpose of applying floodway regulations.

Special Flood Hazard Areas. Areas in a community that have been identified as susceptible to a one-percent or greater chance of flooding in any given year. A one-percent-probability flood is also known as the 100-year flood or the base flood. Special Flood Hazard Areas are usually designated on the Flood Hazard Boundary Map (FHBM) as Zone A. After detailed evaluation of local flooding characteristics, the Flood Insurance Rate Map (FIRM) will refine this categorization into Zones A, A0, A1-30, and V1-30.

Transpiration. The process by which water vapor escapes from a plant through its leaf system and enters the atmosphere.

Watershed. An area from which water drains to a single point; in a natural basin, the watershed is the area contributing flow to a given place or a given point on a stream.

Water Table. The uppermost zone of water saturation in the ground.

Federal Emergency Management Agency Regional Offices

The Federal Emergency Management Agency (FEMA) was created in 1978 to provide a single point of accountability for all federal activities related to disaster mitigation and emergency preparedness and response. It was established as an independent agency in the executive branch to consolidate a variety of existing agencies and offices performing related functions. The Federal Insurance Administration (FIA), formerly a part of the Department of Housing and Urban Development, is only responsible for insurance activities. FEMA is responsible for administering the National Flood Insurance Program. This responsibility includes assisting state and local governments in the implementation of floodplain management programs and providing information on flooding to communities and individuals. Regional offices are the primary means by which FEMA's programs are carried out at the state and local level.

Federal Emergency Management Agency Regional Offices and Boundaries

Region I Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island & Vermont

442 J. W. MacCormack Office Building
Boston, Massachusetts
02109
(617) 223-2616

Region II New Jersey, New York, Puerto Rico & Virgin Islands

26 Federal Plaza
Rm. 1349
New York, New York
10007
(212) 264-4756

Region III Delaware, District of Columbia, Maryland, Pennsylvania, Virginia & West Virginia

Curtis Building
Sixth & Walnut Streets
Philadelphia, Pennsylvania
19106
(215) 597-9416

Region IV Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina & Tennessee

1375 Peachtree Street, N.W.
Suite 778
Atlanta, Georgia
31792
(404) 881-2391

Region V Illinois, Indiana, Michigan, Minnesota, Ohio & Wisconsin

1 North Dearborn Street
Chicago, Illinois
60602
(312) 353-0757

Region VI Arkansas, Louisiana, New Mexico, Oklahoma & Texas

Federal Regional Center
Rm. 206
Denton, Texas
76201
(817) 387-5811

Region VII Iowa, Kansas, Missouri & Nebraska

Federal Office Building
Rm. 405
Kansas City, Missouri
64106
(816) 374-2161

Region VIII Colorado, Montana, North Dakota, South Dakota, Utah & Wyoming

Federal Regional Center
Building 17
Denver, Colorado
80225
(303) 234-6582

Region IX Arizona, California, Hawaii & Nevada

211 Main St.
Rm. 220
San Francisco, California
94105
(415) 556-3543

Region X Alaska, Idaho, Oregon & Washington

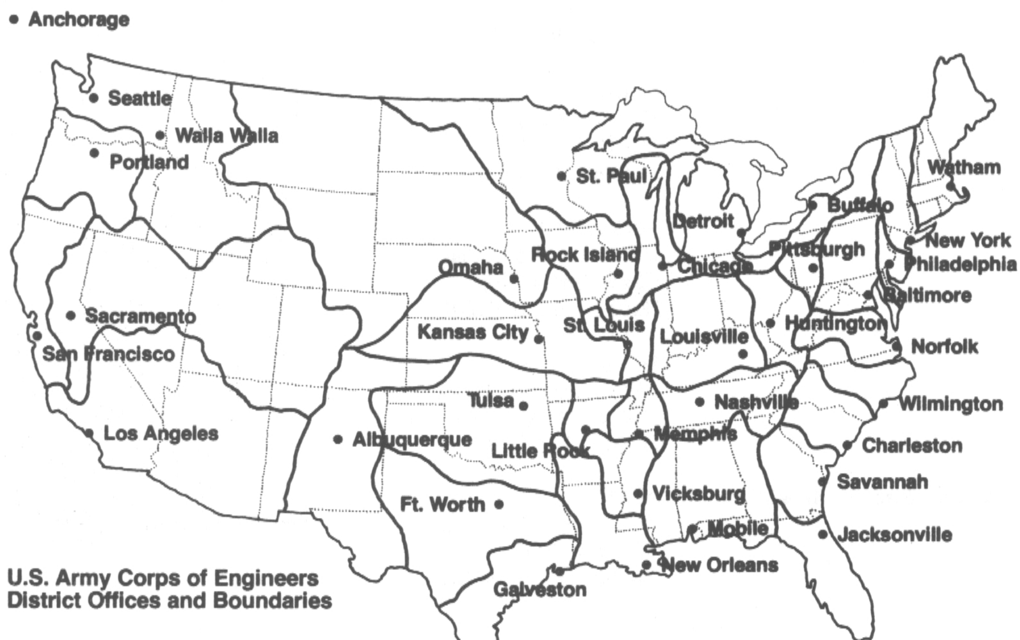
Federal Regional Center
Bothell, Washington
98011
(206) 486-0721

Ted Carland, American Red Cross

U.S. Army Corps of Engineers District Offices

The Corps of Engineers is involved in a variety of flood-related activities, including research and development, planning, design, construction, operation and maintenance. It also engages in real estate activities related to rivers, harbors, and waterways and administers laws for protection and preservation of navigable waters and related resources such as wetlands.

The Corps is organized into 11 divisions and 36 districts based on riverbasins and watersheds. The districts are the principal planning and implementation offices of the Corps, and include an office of Floodplain Management Services. It is authorized to provide information, technical assistance, and guidance to nonfederal entities in identifying the magnitude and extent of flood hazards and in planning wise use of floodplains. It can identify areas subject to flooding and describe flood hazards at specific sites. This information is a basis for planning floodplain use, delineating boundaries for floodplain regulations, and setting appropriate elevations for floodproofing.



U.S. Army Corps of Engineers District Offices and Boundaries

Lower Mississippi Valley Division

Memphis
U.S. Army Engr. Dist.
668 Clifford Davis Federal Building
Memphis, Tn. 38103

New Orleans
U.S. Army Engr. Dist.
P.O. Box 60267
New Orleans, La. 70160

St. Louis
U.S. Army Engr. Dist.
210 Tucker Blvd. N.
St. Louis, Mo. 63101

Vicksburg
U.S. Army Engr. Dist.
P.O. Box 60
Vicksburg, Ms. 39180

Missouri River Division

Kansas City
U.S. Army Engr. Dist.
700 Federal Bldg.
Kansas City, Mo. 64106

Omaha
U.S. Army Engr. Dist.
6014 USPO & Courthouse
Omaha, Ne. 68102

North Atlantic Division

New England
U.S. Army Engineering Division,
424 Trapelo Road
Waltham, Ma. 02154

Baltimore
U.S. Army Engr. Dist.
P.O. Box 1715
Baltimore, Md. 21203

New York
U.S. Army Engr. Dist.
26 Federal Plaza
New York, NY 10007

Norfolk
U.S. Army Engr. Dist.
803 Front St.
Norfolk, Va. 23510

Philadelphia
U.S. Army Engr. Dist.